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STUDY OF PHYSICAL, MECHANICAL AND THERMAL PROPERTIES OF UNIDIRECTIONAL JUTE FIBER REINFORCED PVC FILM COMPOSITES

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ABSTRACT

This paper presents the physical, mechanical and thermal properties of unidirectional jute fiber reinforced polyvinyl chloride (PVC) film composites. Composites (wt % of fiber) of jute fiber reinforced PVC matrix were prepared by compression molding at 160° C. Variable weight ratios of these composites namely 100:0, 95:5, 90:10, 85:15 and 80:20 were prepared and then physical, mechanical and thermal properties were studied. The tensile strength of composites increases with the increase of fiber addition and percentage of elongation at break decreases with increase of fiber addition. Thermal analysis of PVC-jute fiber composites show that thermal degradation of PVC film starts ahead of jute fiber and the degradation of composites was occurring in two stages.

Key Words: PVC, composites, compression molding, tensile strength and thermal degradation.

1. INTRODUCTION

Composites are combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets or particles and are embedded in the other materials called matrix phase. The reinforcing and the matrix materials can be metal, ceramic, or polymer. Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. Fiber matrix interactions play a crucial role in determining the properties of their relative composites [1]. Polymer science and technology is one of the most active and promising fields in science, embracing a multitude of topics natural polymers such as cellulose, wool, silk, jute, palm fiber etc. which are of outmost importance for living systems, to the synthetic high polymer [2].

Growing environmental awareness throughout the world has triggered a paradigm shift towards designing materials compatible with the environment. The use of jute fiber, derived from annually renewable source, as reinforcing fibers in both thermoplastic and thermosetting matrix composites provides positive benefit with respect to ultimate disposability and raw materials utilization. Because of lower density, easy processibility, biodegradability and availability in nature, combined with a better cost performance ratio, cellulosic materials show bright potentiality as filler in thermoplastics. The composites of engineering polymers combined with natural components like wood, flax, hemp, jute, etc. are intensively studied due to the ecology and interesting physical properties of such natural cellulosic materials. Natural fibers such as jute, coir, palm, wood fiber, palm fiber, banana, etc. are used as an alternative to synthetic fibers e.g. glass, aramid, carbon, etc. These fibers are used due to their renewable character, acceptable specific strength properties, low cost, enhanced energy recovery and biodegradability. Natural fiber reinforced polymer combines good mechanical properties with low specific mass. The jute fiber can be used as reinforcing agent in thermoplastics like polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC) etc [3-4]. Lavia Danyadi *et al.* [5] have studied wood flour filled polypropylene composites. The addition of components was modified by two maleic anhydride functionalized PP with different maleic anhydride content and molecular weight. Tensile properties were measured and micromechanical deformation possesses were followed by acoustic emission as well as volume strain measurements in PP/Wood flour composites. Jamal Mirbagheri *et al.* [6] have studied the tensile properties of wood flour/kenal fiber PP hybrid composites. PP was used as the polymer matrix and 40-80 mesh kenaf fiber and 60-100 mesh wood flour were used as the fiber and the particulate reinforcement, respectively. The hybrid effect on the elastic modulus of the composites was investigated using the role of hybrid mixtures and Halpin-Tsai equations. The result indicated that while non-hybrid composites of kenal fiber and wood flour exhibited the highest and lowest modulus values, respectively. Y. Cao *et al* [7] have studied the mechanical properties of biodegradable composite with bagasse fiber before and after alkali treatment. Mechanical properties of the composites made from alkali treatment fibers were superior to the untreated fibers. Composites with 1% NaoH solution treated fibers showed maximum improvement. A. A. Kafi *et al* [8] have studied the mechanical properties of jute/glass fiber reinforced unsaturated polyester hybrid composites. The change in tensile and flexural properties as a function of fiber content and as a consequence of UV radiation was investigated. It had been observed that radiation treatment on both the jute and glass fiber maintaining 1:3 ratios gives the best mechanical property. The mechanical and thermal properties of unidirectional jute-vinyl ester composites have been studied by M.A. Khan and S.K. Bhattacharia [9]. This study established the relationship of interfacial bond strength between 2-hydroxyethyl methacrylate treated jute fiber and vinyl ester in the composites.

2. EXPERIMENTAL DETAILS

2.1 Sample preparation methodology

The PVC sheets and jute fibers were cut into length of 152.4 mm with the help of scissor. The composites were made for different ratio of PVC and jute (100:0, 95:5, 90:10, 85:15 and 80:20 weight %). Each layer of PVC was preimpregnated with jute fibers and placed one over another as a sandwich making system. The sandwich was then subjected to heat of 160^0 C for 1 hour and pressure of 100 KN. The holding time was taken about 10 minutes. Then the system was allowed to cool by tap water.

2.2 Measurements of physical properties

To measure bulk density, the sample was weighted on a balance to a precision of ± 0.1% and then volume was measured with the help of length, width and height. To measure water absorption properties, the specimens were cut from the molded sheets and weighted by a digital balance. All specimens were then placed in a container of distilled water with temperature 50^0 C and kept their for different times (0.5, 1, 2, 3 and 4 hours). The samples were periodically taken out from water and wiped off with tissue paper. The samples were then re-weighted to the nearest 0.0001 gm.

2.3 Measurements of mechanical properties

The tensile test was carried out by using an NC machine to determine tensile strength and elongation of the specimen. The test speed was 500 mm/min. Bar shaped specimens having dimension 5 cm ×1.3 cm × 0.06 cm (up to 0.12 cm) with rectangular cross-sections were prepared for flexural measurements. Flexural measurements were performed to a freely supported beam, loaded at mid-span. The loading speed was 1 mm/min and support-span was 38 mm in dimension.

2.4 Measurements of thermal properties

Thermal properties of the samples were monitored by a coupled Differential Thermal Analyzer (DTA) and Thermo Gravimetric Analyzer (TGA). Composites were taken using a computer controlled to an EXSTAR 6000 STATION, Seiko Instrument Inc. Japan. The TGA/DTA module uses a horizontal system balance machine. The specifications of the instruments were: heating rate: 0.1 K/min. to 100.00 K/min, TGA measuring range: ±200 mg (0.2μg), DTA measuring range: ± 100μV (0.06 μV), Gas flow: ≦ 1000 mm/min.

3. RESULTS AND DISCUSSION

3.1 Physical properties analysis

3.1.1. Bulk density

The effect of variation on the wt. % of jute on the density of jute reinforced PVC composites is illustrated in Fig. 1. It is evident that the density of jute-PVC composites decreases with increasing of the amount of jute. This is due to the lower density of jute fiber. The bulk density decreases from 1.42 to 1.29 gm/cc, when the amount of jute increases from 0 to 20 wt. %.

3.1.2. Water absorption

The effect of immersion time on water absorption of PVC-jute fiber composites is presented in Fig. 2. It is found that the amount of water absorption in composites is increasing with increasing soaking time. The cellulosic effect, the lignin effect and also void spaces present in the composites might be responsible for the increase of water absorption with soaking time.

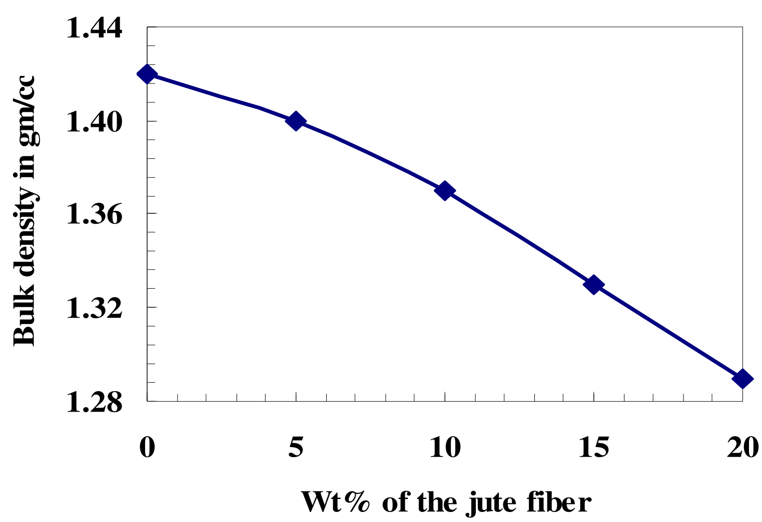

Figure 1: Effect of jute fiber addition on density of jute-PVC composites

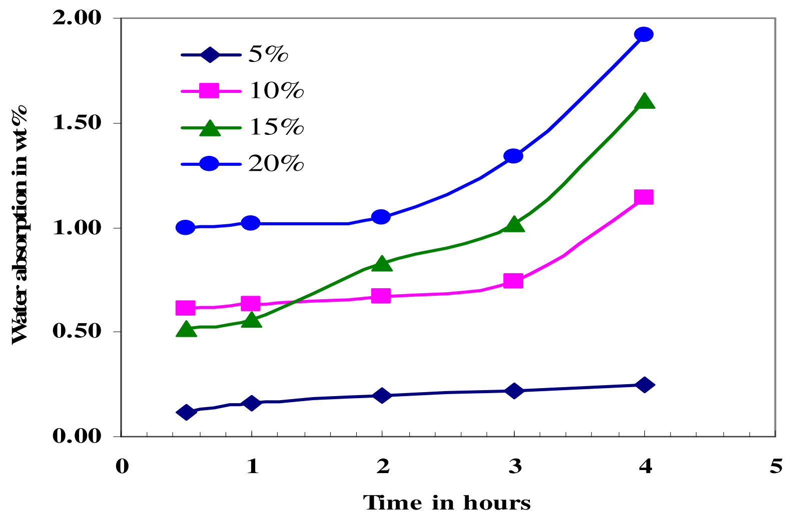

Figure 2: Effect of immersion time on water absorption of PVC-jute fiber composites

3.2 Mechanical properties analysis

3.2.1. Tensile strength

Fig. 3 shows the variation of tensile strength with wt. % of jute in PVC-jute fiber composites. The tensile strength of the fabricated composites increases with increase of filler addition. This is because the fibers are well distributed, interfacial bonding between the fiber and matrix is excellent and both the fiber and matrix bear the load and fibers make resistance to slip.

3.2.2. Elongation break

Fig. 4 represents the effect of jute fiber addition on elongation break. It reveals that the presence of fiber addition restricts the slip resulting in lesser ductility and consequently the % of elongation decreases with increase of jute fiber addition. It also reveals that the randomly oriented jute fiber is reinforcing the PVC matrix and from 0% to 20% fiber addition both the fibers and matrix bear the load.

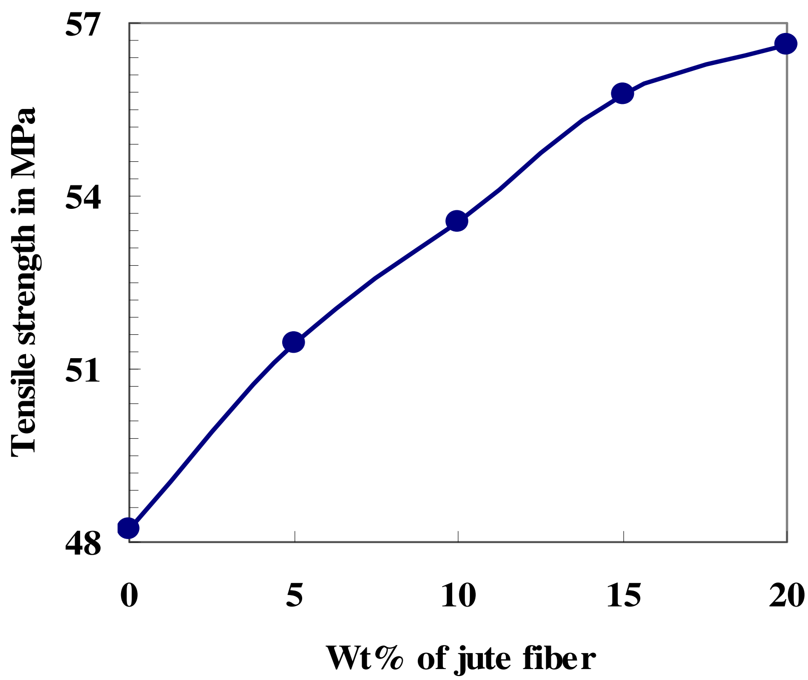

Figure 3: Effect of variation of wt % of jute on the tensile strength.

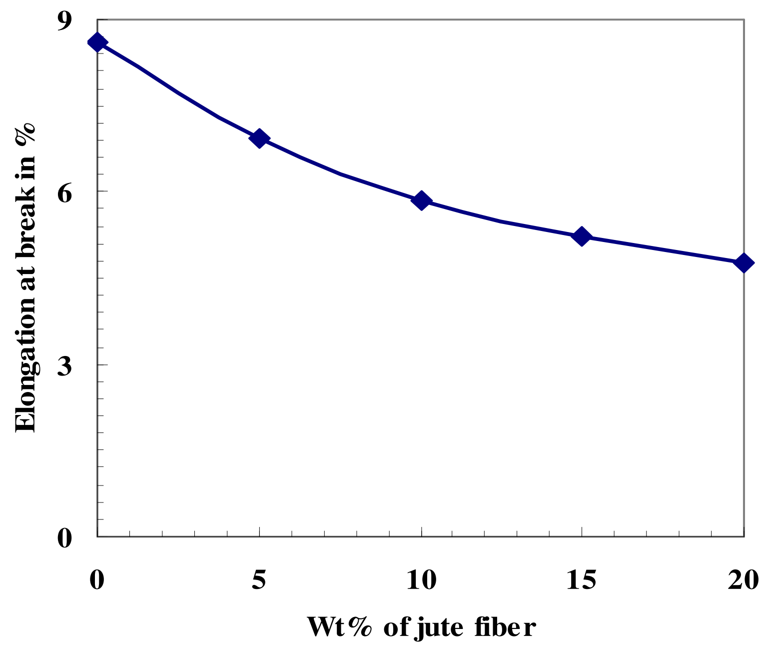

Figure 4: Effect of variation of wt % of jute on % elongation

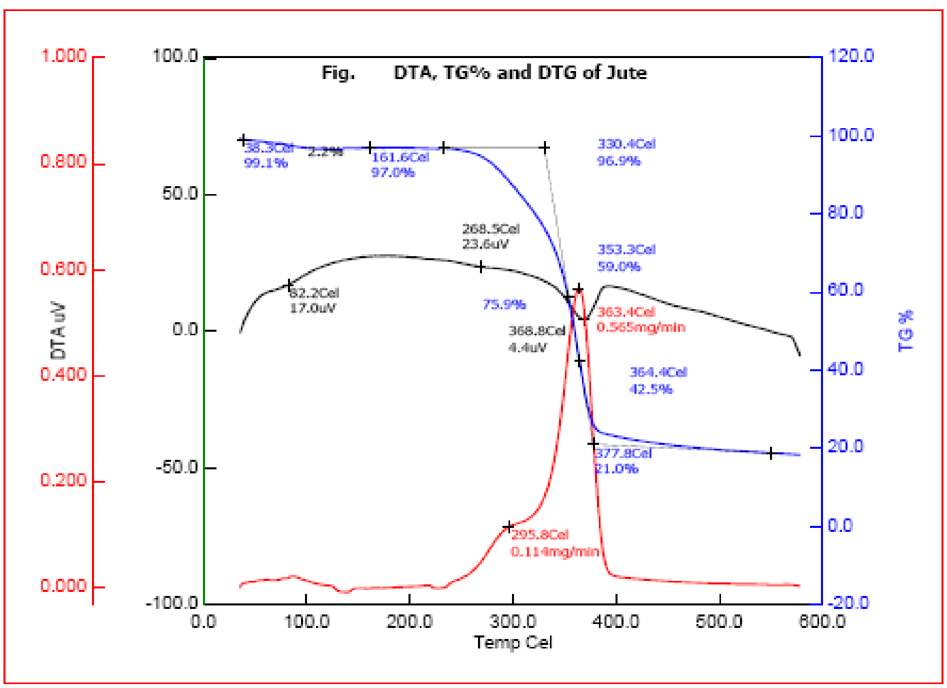

Figure 5: TG, DTA and DTG of jute fiber.

3.2 Thermal properties analysis

Fig. 5 shows the TG, DTA and DTG of jute fiber. The top one is the TG, the bottom one is the DTG and the middle one is the DTA curve of jute fiber. The TG curve shows an initial 2.2% loss corresponds to moisture content. The lighter substances are removed initially and then heavier materials are removed. The TG curve shows that major degradation occurs in one stage. DTA curves of jute fiber shows three endothermic peaks at 82.2^0 C, 268.5^0 C and

368.8^0 C. The first peak at 82.2^0 C is due to removal of moisture, the second peak is due to lighter material and the third peak corresponds to major degradation respectively. Two DTG peaks were found at 295.8^0 C and 363.4^0 C which are correspondent to lighter and heavier material. The maximum degradation occurs at the temperature 363.4^0 C with the rate of 0.565 mg/min. Fig. 6 shows the TG, DTA and DTG curves of PVC film. The top one is the TG, the bottom one is the DTG and middle one is the DTA curves of PVC.

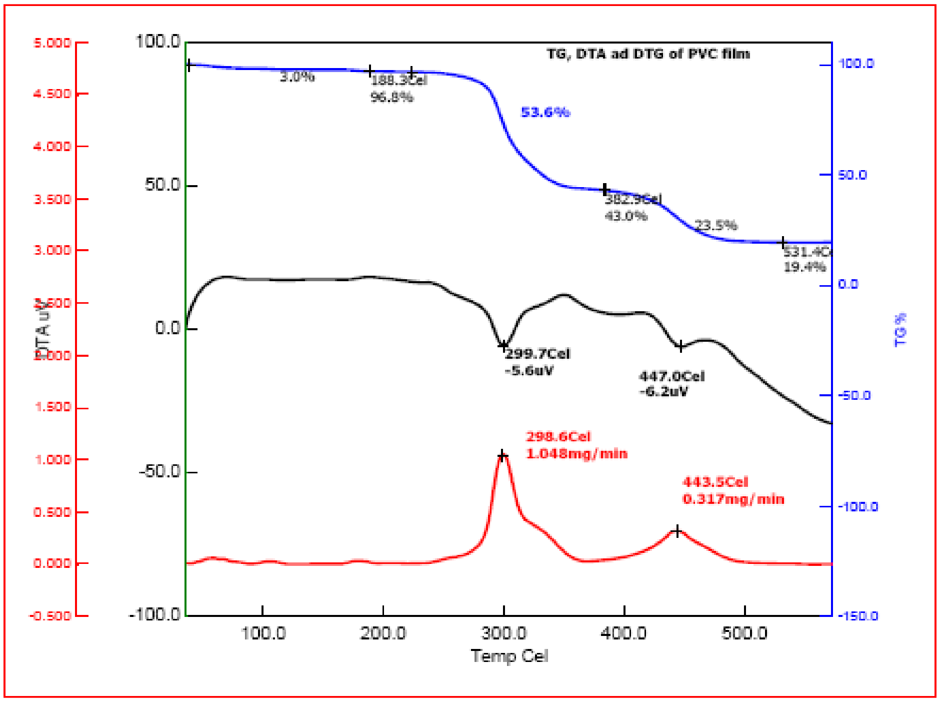

Figure 6: TG, DTA and DTG of PVC film.

The TG curve shows that the major degradation occurs at two stages for the PVC. DTA curve of PVC shows two endothermic peaks at 299.7^0 C and 447.0^0 C. Two DTG peaks are found at 298.6^0 C and 443.5^0 C. The peaks are for de hydro chlorination and de polymerization. DTG curve of PVC depicts that the maximum degradation occurs at the temperature 298.6^0 C with the rate of 1.048 mg/min. Fig. 7 shows the TG, DTA and DTG curves of PVC-jute composites. The top one is the TG, bottom one is the DTG and middle one is the DTA curves for PVC-jute composites.

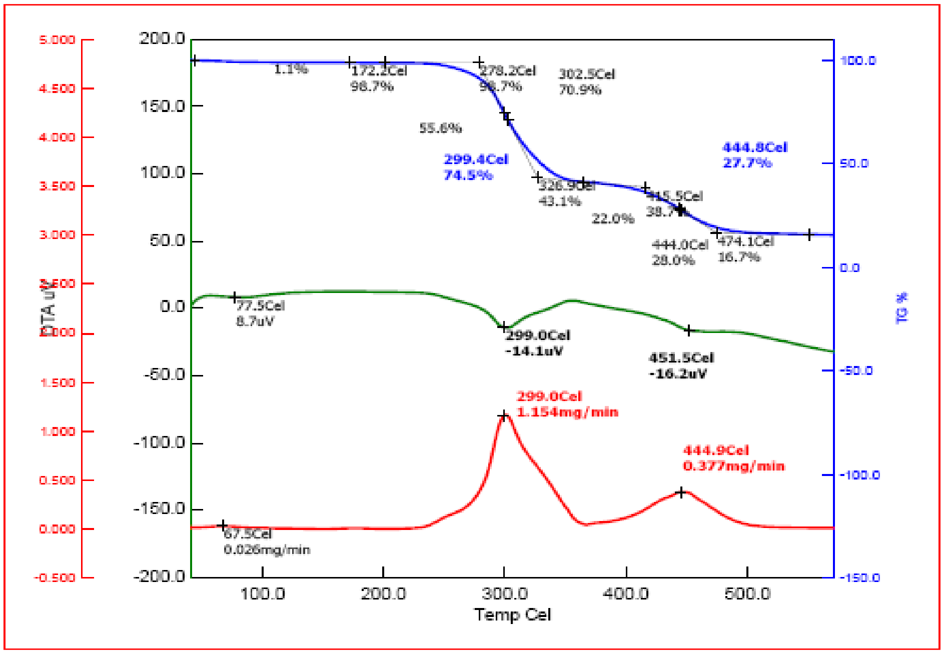

Figure 7: TG, DTA and DTG of PVC-jute composites.

The TG curve shows that the major degradation occurs at two stages for the composites. The TG curve also shows an initial loss of 1.1% which is due to moisture content. DTA curve of composite shows three endothermic peaks at 77.5^0 C, 299.0^0 C and 451.5^0 C. The DTG curve also reveals that there are two peaks at the temperature of 299.0^0 C and 444.9^0 C. DTG curve of composites depicts that the maximum degradation occurs at the temperature 299.0^0 C with the rate of 1.154 mg/min. Fig.8 shows the TG, DTA and DTG curves of PVC film, jute and composites. The black curve is for PVC film. The red curve is for jute fiber and the blue curve is for composites. The thermal stability of composites is found to be the average of PVC and jute fiber (long) composites. All the data are represented in Table 1.

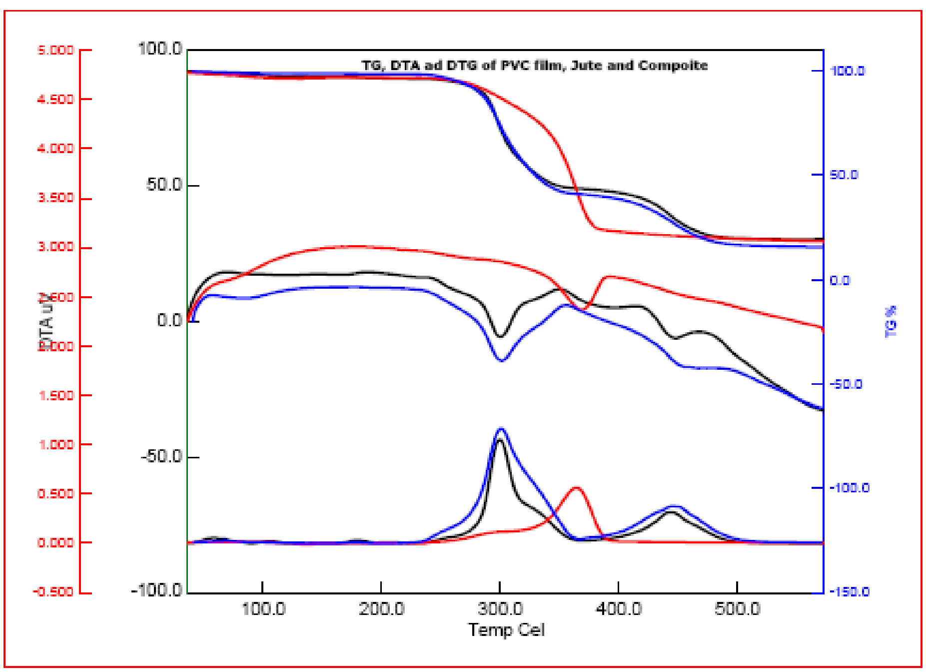

Figure 8: TG, DTA and DTG of PVC film, jute and composites.

Table 1: DTA and DTG data of jute fiber, PVC film and composites

Sample	1st peak	2nd peak	3rd peak	Maximum at (°C)	Degradation rate mg/min
Jute fiber	82.2	268.5	368.8	363.4	0.565
PVC film	299.7		447.0	298.6	1.048
Composites	77.5	299.0	451.5	299.0	1.154

4. CONCLUSIONS

Jute-PVC composites demonstrate good mechanical strength and can be used as environmentally degradable thermoplastics. The bulk density of fabricated composites decreases with increase of fiber addition. The tensile strength of jute-PVC composites increases with the increase of fiber addition. Water absorption increases with the increase of soaking time because with the addition of fiber the composites were more prone to water. The TG, DTG and DTA curves of composites are the average of jute fiber and of PVC. The degradation of composites was occurring in two stages. The thermal stability of PVC-jute fiber (long) composites is higher than that of jute fiber but lower than that of PVC film.

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